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Colorado Div. of Wildlife, Fort Collins

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Environmental Effects of Oil Shale Mining and Processing

Part I: Fishes of Piceance Creek, Colorado, Prior to Oil Shale Processing

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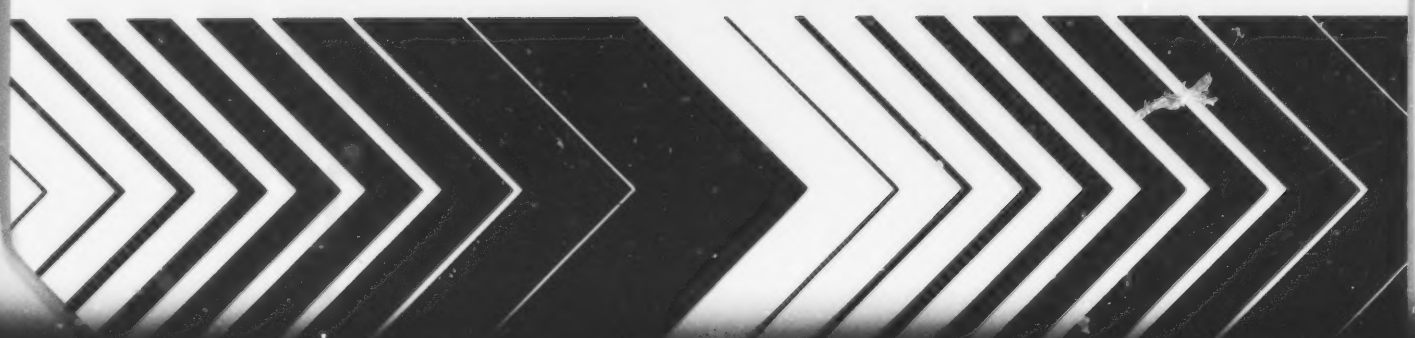

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16. ABSTRACT

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The mountain sucker (*Catostomus platyrhynchus*) and the speckled dace (*Rhinichthys osculus*) are the most abundant and widespread fishes found in Piceance Creek. Numbers of all species were not great; the largest number of fish captured per 100 meters of stream was 76 individuals, while the range for all other stations was 3-23 fish/100 m. Brook, brown, and rainbow trout (*Salvelinus fontinalis*, *Salmo trutta*, and *Salmo gairdneri*, respectively) were most common in the upper reaches of Piceance Creek and in its tributaries, Black Sulphur Creek and Stewart Creek. Results of our survey indicate that brook and brown trout are reproducing naturally in Piceance Creek but rainbow trout are doing poorly. The introduction of species from other drainages and the effects of agricultural diversions and riparian alterations have produced recent changes in the fish fauna of Piceance Creek. Possible impacts of oil shale processing on the fish populations of Piceance Creek are suggested.

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ENVIRONMENTAL EFFECTS OF OIL SHALE MINING AND PROCESSING
PART I - FISHES OF PICEANCE CREEK, COLORADO, PRIOR TO OIL SHALE PROCESSING

by

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FOREWORD

This report contains the data from a preoperational biological survey of the fishes in Piceance Creek, Colorado where oil shale development is anticipated. It is one of a series of reports all intended to better describe energy development impacts on aquatic environments in the West. The value of this report will increase in future years because it will become a reference point in time by which changes in Piceance Creek will be judged.

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Director
Environmental Research Laboratory-Duluth

ABSTRACT

The fish populations of Piceance Creek, Colorado, were surveyed to establish preoperational conditions prior to extensive oil shale processing in the region. Data collected in this study have been compared to data reported by earlier researchers.

The mountain sucker (*Catostomus platyrhynchus*) and the speckled dace (*Rhinichthys osculus*) are the most abundant and widespread fishes found in Piceance Creek. Numbers of all species were not great; the largest number of fish captured per 100 meters of stream was 76 individuals, while the range for all other stations was 3-23 fish/100 m. Brook, brown, and rainbow trout (*Salvelinus fontinalis*, *Salmo trutta*, and *Salmo gairdneri*, respectively) were most common in the upper reaches of Piceance Creek and in its tributaries, Black Sulphur Creek and Stewart Creek. Results of our survey indicate that brook and brown trout are reproducing naturally in Piceance Creek but rainbow trout are doing poorly. The introduction of species from other drainages and the effects of agricultural diversions and riparian alterations have produced recent changes in the fish fauna of Piceance Creek. Possible impacts of oil shale processing on the fish populations of Piceance Creek are suggested.

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SECTION I

INTRODUCTION

The Green River Oil Shale Formation in Colorado, Utah, and Wyoming is estimated to contain 80 billion barrels of recoverable oil, an amount capable of sustaining domestic U.S. consumption for 20 years (Yen 1976). The development of this energy resource will require the disposal of 732,000 tons/day of spent shale by the year 1987. This would provide a possible source of leachates to local water courses including Piceance Creek and its tributaries. Among the materials that could be leached from spent oil shale are mutagenic polycyclic aromatic compounds and salts (Schmidt-Collesus et al. 1976). In addition, Moussavi and Yen (1976) have suggested that salt water springs may enter disrupted aquifers in the mining area. Oil shale mining and processing has, therefore, the potential to alter the water quality of Piceance Creek and thereby adversely affect its fish populations. The following study was undertaken to gather information on the fish populations of Piceance Creek prior to the start of oil shale mining and processing.

Fish populations have been systematically sampled in Piceance Creek, Colorado, during various investigations since 1969 when Everhart and May (1973) surveyed the biota of this stream. Their report included a list of fishes collected during their survey, but collection sites and numbers of specimens captured were not included. In 1974 the consulting firm of Woodward-Envicon began a series of reports to the U.S. Geological Survey Area Oil Shale Supervisor in Grand Junction, Colorado, concerning their findings related to the Environmental and Exploration Program in Oil Shale Tract C-b for the lessees of this tract. These reports include accounts of sampling locations and the numbers and sizes of fishes collected in Piceance Creek but their effort was concentrated at stations near or above Black Sulphur Creek, a tributary to Piceance Creek.

The major objectives of the present study were to determine what species of fishes currently inhabit Piceance Creek and to find out where they occur. In addition, an attempt was made to summarize previous work on the distribution of fishes in the Piceance Creek basin. Stations were chosen so that they overlapped the stations sampled by previous investigators.

SECTION II

CONCLUSIONS

(1) Comparison of our data to those of earlier workers presents evidence indicating that the fish species composition is changing in Piceance Creek and that some species are extending their distributional ranges.

(2) Distributional and compositional changes in the fishes of Piceance Creek probably result from both the introduction of non-native fish species and degradation of the habitat caused by agriculturally related alterations of the streambanks and associated vegetation.

(3) There is evidence that the lower reaches of Piceance Creek are used as spawning areas for fishes from the White River, although the relative importance of Piceance Creek to the populations of fishes in the White River has not been determined.

(4) Trout are not common in Piceance Creek below Black Sulphur Creek, possibly due to the high turbidity, salinity, and summer water temperatures encountered in this area. Upwelling from the lower aquifer through a fault at Black Sulphur Creek accounts for the sharp decrease in water quality at this point.

(5) Reductions in flow in Piceance Creek may first impact on the salmonid species, and increases in salinity may first impact on the non-salmonid species.

SECTION III

RECOMMENDATIONS

(1) Disruptions of aquifers caused by either aboveground or *in situ* oil shale processing which result in reduced water flow, increased salinity, or other detrimental physical or chemical changes in Piceance Creek should be avoided.

(2) A field investigation similar to this study should be conducted after oil shale processing at the Colorado C-b site has reached a more advanced stage so that possible future changes in Piceance Creek may be studied.

(3) Laboratory and conjunctive field studies on the toxic effects to fishes of saline waters of different ionic composition should be conducted.

SECTION IV

METHODS

Fishes were collected during the fall of 1975 at five stations on Piceance Creek and at one station on each of its tributaries, Stewart Creek and Black Sulphur Creek. In addition, six stations on Piceance Creek proper and two new stations near the White River were sampled during summer 1976 (Figure 1). Stations PC-1 through PC-4 were sampled both in 1975 and 1976, and all other stations were sampled either in 1975 or 1976. Two of our stations were near to those sampled by Woodward-Envicon from September 1974 to August 1976. Our stations were chosen to represent nearly all of the Piceance basin.

Fish were sampled in the first year using a Coffelt Model BP-3 backpack shocker. One or two passes with the shocker over approximately 100 m of streambed constituted a sample. Data collected the first year were not used for population estimates. In 1976, a 100-m stream section was also sampled at each station above PC-4; however, for these samples, three passes of the shocker were completed at each station. Fish population estimates were calculated using the method of Leslie and Davis (1939). Conductivities at stations downstream from Station PC-4 were sufficiently high to preclude the use of even the high-wattage generator used during the 1976 sampling; thus, a seine was used to capture fish at these stations. Species composition was the only information derived at stations which were seined.

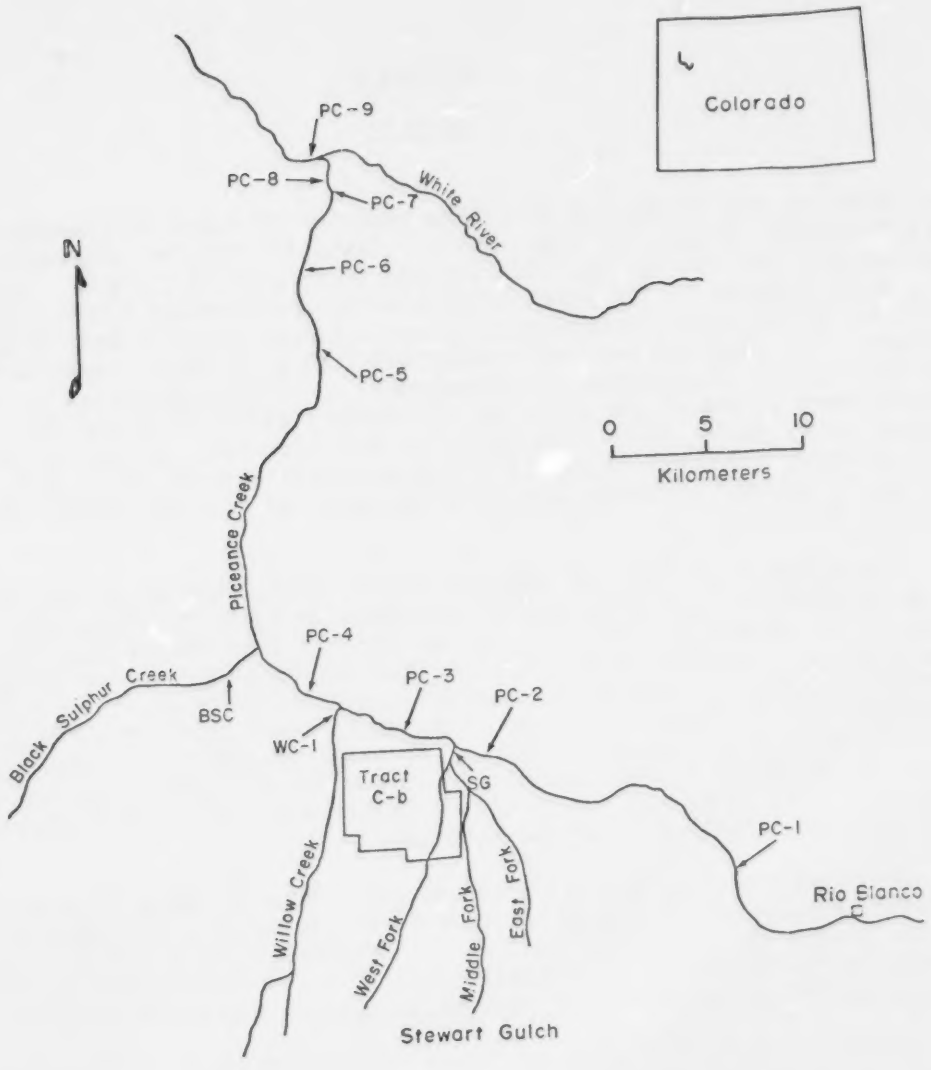

Figure 1. Piceance Creek and major tributaries, Colorado, showing sampling locations, and one oil shale lease site (Tract C-b).

SECTION V

RESULTS

Eight of the 13 species of fishes reported to occur in Piceance Creek were recovered in our sampling. Table 1 lists the species and numbers of each species per station for the 1975 and 1976 sampling periods. Salmonids were most numerous at the three upper stations on Piceance Creek. In addition, brook trout (*Salvelinus fontinalis*) were found in both tributary streams. The dominant and most widespread fish of Piceance Creek was the mountain sucker (*Catostomus platyrhynchus*) Population estimates of this species were 61 and 36 per 100 m of stream at Stations PC-2 and PC-3, respectively, during 1976. The speckled dace (*Rhinichthys osculus*) and mottled sculpin (*Cottus bairdi*) are common inhabitants of many small streams in western Colorado, but only the speckled dace was common in Piceance Creek.

Measurements of flow and specific conductance taken at various stations on the same dates fish were sampled are shown in Table 2. Flow measurements taken at the upper four stations during 1975 and 1976 showed that the 1975 flow averaged 1.9 times that which occurred during 1976. An unexpected short-term change in conductivity occurred at Station PC-8, where 2,200 µmhos measured on August 11, 1976 increased to 3,400 µmhos the following day with no apparent change in flow. Increased conductivities usually accompany decreased flows; however, localized thunderstorms occurred in the area about this time, and the resulting runoff may have drained an exceptionally salt-laden local area of the watershed.

While our stations did not coincide entirely with those of previous investigators, we found nearly the same fish species as other workers at the two common stations (PC-2 and PC-4). Previous reports differ with respect to the salmonids' distribution but this is probably attributable to differences in collection dates and the salmonids' migratory patterns.

Table 3 lists all species of fishes reported to occur in Piceance Creek. Only the mountain sucker, speckled dace, and rainbow trout are represented in the reports of all investigators. The following is an account of each species of fish reported from Piceance Creek.

Mountain whitefish

Mountain whitefish are found primarily in large, clear, cold rivers and prefer the deep, fast moving waters (Baxter and Simon 1970). Our observations show that during the fall months both adult and immature

TABLE 1. NUMBER OF FISH CAPTURED PER 100 M OF STREAM AT SEVEN STATIONS ON PICEANCE CREEK, COLORADO, AND AT ONE STATION ON EACH OF TWO TRIBUTARIES

Species / Date	Station								
	PC-1	PC-2	PC-3	PC-4	PC-7	PC-8	PC-9	SG	BSC
Rainbow trout									
11/75	0	0	0	0	0	--[a]	--	0	0
8/76	0	2	0	0	--	0	0	--	--
Brown trout									
11/75	0	0	1	0	0	--	--	0	0
8/76	0	2	0	0	--	1	0	--	--
Brook trout									
11/75	0	0	2	0	0	--	--	4	5
8/76	0	0	0	0	--	0	0	--	--
Speckled dace									
11/75	1	0	0	3	3	--	--	2	0
8/76	0	17	1	0	--	2	5	--	--
Red shiner									
11/75	0	0	0	0	0	--	--	0	0
8/76	0	0	0	0	--	0	1	--	--
Mountain sucker									
11/75	19	0	4	8	0	--	--	0	3
8/76	3	55	11	3	--	1	0	--	--
Flannelmouth sucker									
11/75	0	0	0	0	0	--	--	0	0
8/76	0	0	0	0	--	0	6	--	--
Mottled sculpin									
11/75	0	0	0	0	0	--	--	0	0
8/76	0	0	0	0	--	1	3	--	--

[a]Denotes no sampling.

TABLE 2. SPECIFIC CONDUCTANCE AND STREAM FLOWS AT SEVEN STATIONS ON PICEANCE CREEK AND AT ONE STATION ON EACH OF TWO OF ITS TRIBUTARIES DURING 1975-1976

Station	Date	Conductivity (μmhos)	Flow (m^3/sec)
PC-1	11-22-75	1150	0.089
	8-11-76	1400	0.109
PC-2	11-22-75	1625	0.702
	8-11-76	1650	0.409
PC-3	11-23-75	1800	0.951
	8-12-76	2000	0.421
PC-4	11-23-75	1850	0.943
	8-11-76	2200	0.337
PC-5	11-23-75	2050	1.310
PC-7	11-22-75	2400	2.06
PC-8	8-12-76	3400	1.15
SG	11-24-75	2000	0.057
BSC	11-24-75	2200	0.351

TABLE 3. FISH SPECIES REPORTED BY VARIOUS INVESTIGATORS IN PICEANCE CREEK, COLORADO

Scientific name	Common name	Present report 1975-1976	Everhart and May (1973)	Ashland Oil and Shell Oil Tract C-b (1975)	Pettus (1974)
Prosopium williamsoni	Mountain whitefish		X		
Salmo gairdneri	Rainbow trout	X	X	X	X
Salmo trutta	Brown trout	X		X	
Salvelinus fontinalis	Brook trout	X	X	X	
Gila robusta	Roundtail chub		X		
Ictalurus melas	Black bullhead		X		
Notropis lutrensis	Red shiner	X	X		
Pimephales promelas	Fathead minnow				X
Rhinichthys osculus	Speckled dace	X	X	X	X
Catostomus commersoni	White sucker				X
Catostomus latipinnis	Flannelmouth sucker	X	X	X	
Catostomus platyrhynchus	Mountain sucker	X	X	X	X
Cottus bairdi	Mottled sculpin	X	X		

whitefish move into the lower reaches of Trout Creek, a stream similar in size and elevation to Piceance Creek (Goettl and Edde, in prep.). Similarly, Brown (1952) reported that some mountain whitefish migrate upstream into small tributaries during the fall spawning season. We did not find mountain whitefish during our sampling but they were reportedly collected by Everhart and May (1973). The location where Everhart and May took this species in 1969 was not reported, but it was likely near the White River since whitefish are known to occur there in great numbers. With the possible exception of spawning runs, the impact of oil shale exploitation on this species would be limited to the White River.

Brook trout

There is a 3-m waterfall in Piceance Creek located approximately 3-4 km below the point where Stewart Gulch joins Piceance Creek, and immediately upstream from Station PC-3. This waterfall may block upstream movement of brook trout at that point. Because of this barrier, there are probably at least two populations of brook trout in Piceance Creek and its tributaries. Adequate spawning areas for brook trout are available both downstream from the waterfall, in Black Sulphur Creek, and above the waterfall in Lower Stewart Lake, a spring-fed pond located near the mouth of Stewart Gulch. Spawning may also occur in Piceance Creek itself. In addition, optimal temperatures for growth of brook trout (McCormick et al. 1972) have been reported at stations along Piceance Creek upstream from Black Sulphur Creek during the months June to September (Everhart and May 1973). Even at the mouth of Piceance Creek lethal temperatures for brook trout were exceeded only during these months.

Our collections included small numbers of brook trout, some of which exceeded 38 cm total length. Woodling (1974) suggested that the small brook trout population characterized by a few abnormally large individuals probably indicates ". . . a degraded system." However, whether Piceance Creek is degraded, and if it is, the nature of this degradation is not clear. The brook trout populations in the Piceance Creek watershed do not show the patterns of over-population and stunting described by Baxter and Simon (1970). Fishing probably has little influence on the brook trout populations in Piceance Creek because fishing pressure is low (Pettus 1974); consequently, the reason for the seemingly poor status of brook trout in Piceance Creek is not known. Dewatering during oil shale mining would probably have the greatest impact on this species and other headwater species in Piceance Creek.

Rainbow trout

Only two rainbow trout were taken, both at Station PC-2 in 1976. No immature individuals were recovered, indicating little or no natural reproduction. Collections by earlier researchers also indicated that rainbow trout were scarce in Piceance Creek. Because of their scarcity, rainbow trout are currently not important in Piceance Creek.

Brown trout

Brown trout were the most widely distributed salmonid in Piceance Creek and were the only salmonid recovered at Station PC-8. The recovery of an immature brown trout at Station PC-8 indicates that brown trout may reproduce naturally in Piceance Creek. Brown trout are generally more tolerant of higher salinities (Gordon 1959), toxic metals (Grande 1967), and perhaps high temperatures (Vincent and Miller 1969), than other salmonids. Salinity and temperature increase progressively downstream in Piceance Creek; thus brown trout may be the only salmonid able to inhabit the lower reaches if a salinity problem were to develop.

Roundtail chub

Two roundtail chubs were collected at the sampling site near the mouth of Piceance Creek in 1969 by Everhart and May but no subsequent collections have been reported for this species. In Wyoming, Baxter and Simon (1970) describe the roundtail chub occurrence as ". . . mostly in larger rivers, but occasionally in smaller streams;" thus the 1969 fish were likely strays from the White River. Roundtail chub are not likely to become established in Piceance Creek since their preferred habitat does not occur there.

Black bullhead

The black bullhead has not been reported in Piceance Creek since Everhart and May collected it in 1969. Since this species is not common in the White River, its occurrence in Piceance Creek was most likely through artificial introduction. Since black bullhead failed to become established, it is likely that the habitat is poor for the species in Piceance Creek.

Red shiner

Red shiner were infrequently collected from Piceance Creek. The Middle Colorado and Lower Green Rivers seem to be favorable habitat for this species, which was probably introduced near Grand Junction, Colorado, in the late 1950's (Holden and Stalnaker 1975). However, the rapidity with which red shiners exploit favorable habitat and their rarity in Piceance Creek suggests that Piceance Creek does not provide good habitat for this species.

Fathead minnow

This species, which was introduced from the eastern slope of the Continental Divide, has been reported at only one station in the lower part of Piceance Creek. Andrews (1970) reported that, although the fathead minnow was quite tolerant of a wide range of chemical and physical conditions in Colorado streams, it is intolerant of stream velocities exceeding 3 cm/sec. The mean value of 14 surface velocities from five sampling stations throughout Piceance Creek taken in 1976 was 63.5 cm/sec; Piceance Creek is therefore poor fathead minnow habitat.

Speckled dace

The speckled dace was recovered at all stations on Piceance Creek, with only the mountain sucker found in greater numbers. In contrast to the fathead minnow, the speckled dace is highly adapted to fast-flowing water. Moyle (1976) reported that this species is more numerous in channelized sections of streams characterized by rapidly flowing riffle areas with scant cover. Dewatering of favorable habitat, reduced stream flows, and changes in salinity due to disruption of groundwater supplies by oil shale mining could seriously affect this species.

White sucker

Pettus (1974) collected 13 specimens of white sucker at Station PC-7 in 1973, but no other records of this species in Piceance Creek are known. White suckers are omnivorous and tolerant of a wide range of temperatures. They are somewhat more sensitive to turbidity and current than other suckers, although we have collected specimens elsewhere from waters fully as swift and turbid as those of Piceance Creek. The restricted range and small populations of white suckers in Piceance Creek may result from competition with the highly adapted and endemic mountain sucker.

Flannelmouth sucker

We found this species only in the mouth of Piceance Creek, but Ashland Oil, Inc., and Shell Oil Co. (1975) reported one specimen approximately 17 km upstream from the mouth. This was collected in March and may have been a migrant spawner, as this species ascends streams in the spring (Baxter and Simon 1970). Flannelmouth suckers are rare and currently not important in Piceance Creek.

Mountain sucker

Mountain suckers were found at the highest density of any species in Piceance Creek. This species and the speckled dace were the only species collected that are native to this creek; however, the mountain sucker appears somewhat more successful, judging by its greater numbers and larger range. Sixty-one mountain suckers per 100 m of stream were estimated at Station PC-2 in 1976. Smith (1966), in his monograph on the subgenus *Pantosteus*, states "It is usually encountered in small mountain streams 10 to 40 feet wide." Holden and Stalnaker (1975) did not encounter the mountain sucker in their recent extensive survey of the fishes of the middle and upper Colorado River basins, but they sampled only rivers. The majority of small tributaries to these rivers would have probably yielded mountain suckers. This species faced competition from introduced white suckers in Trout Creek (Goettl and Edde, in prep.), a stream similar in size to Piceance Creek. It is therefore conceivable that increasing human populations resulting from oil shale development could increase the chances that an undesirable baitfish capable of out-competing mountain suckers would be introduced into Piceance Creek.

Mottled sculpin

Mottled sculpin were collected using a kick net at Station PC-8 and by seining at PC-9. These were the only stations where sculpins were found in Piceance Creek; however, the habitat appears to be excellent for sculpins throughout the creek. Factors which have been shown to limit sculpin production elsewhere include salinity (Foster 1969) and silt and turbidity (Petrosky and Waters 1975), but these factors appeared to occur in Piceance Creek well within tolerance limits for sculpins. The reason for the limited occurrence of mottled sculpins in Piceance Creek is therefore not known.

SECTION VI

DISCUSSION

Piceance Creek presents a somewhat atypical environment for a stream of its size and elevation. It is properly classified as a mountain stream, but its conductivity frequently achieves values in excess of 3,000 μmhos/cm SEC in its lower reaches. Surface velocities average about 60 cm/sec during summer months. It has a shaly substrate with a considerable amount of fine, sandy material rather than the more typical cobble bottom type. Although the creek is quite small (range of measured flows 0.091-2.06 m^3/sec), the upper reaches of Piceance Creek continue to flow throughout the year due to a considerable input of spring water. The headwaters are presumably blocked to upstream migration of fishes by a 3-m waterfall located between Stations PC-2 and PC-3, although mountain suckers, speckled dace, and three species of introduced trout are found above this barrier.

Only mountain suckers and speckled dace are permanent native residents; they inhabit all reaches of Piceance Creek. Introduced fishes include: black bullhead, red shiner, fathead minnow, white sucker, rainbow trout, brook trout, and brown trout. Of these introduced fishes, only brook trout and brown trout appear to be successfully established. Occasionally migratory native species, including flannelmouth sucker, roundtail chub, and mountain whitefish, are found in Piceance Creek. Presumably these are spawning fishes from the White River. In addition, mottled sculpin occur in the lower reaches but it is not known if they are migrants or residents.

Potential impacts due to oil shale mining include dewatering of headwater spring supplies and changes in salinity due to leaching from oil shale spoils (Skogerboe et al., in prep.).

The impacts of reductions in flow on fish populations have been reviewed by Fraser (1972). Kraft (1968) has shown that a 70-percent reduction in brook trout numbers became apparent only in the third year of a stream study where the flow had been reduced 90 percent. Apparently, brook trout population adjustments to low flows take place over an extended time period. Species such as the mountain sucker, which are more dependent on autochthonous food sources, would probably be more immediately affected by low flows.

Tolerance of different fish species to salinity varies greatly and appears to depend on the life history of a species, its taxonomic position with regard to its marine-freshwater origin, its state of maturity, and the specific composition of the dissolved salts. Three species which occur in Piceance Creek, *Salmo trutta*, *S. gairdneri*, and *Pimephales promelas*, plus a

congener of another Piceance Creek fish, *Cottus morio*, will be used to illustrate these relationships.

Fish which are sometimes anadromous such as *Salmo trutta, S. gairdneri,* and some populations of *Salvelinus fontinalis* are equipped to deal with changes in salinity in their environment. According to Gordon (1959) brown trout can survive direct transfers from freshwater to seawater provided the temperature is 10°C or less. Parry (1960) has reported that rainbow trout are even better suited than brown trout in their ability to survive salinity changes. Chipman (1959) showed that strictly freshwater species which are recently evolved from marine ancestors are more tolerant of high salinity conditions than those species with more remote marine ancestry. A typical example is the sculpin, *Cottus morio*. This freshwater fish is of recent marine origin, and can tolerate as much as 75 percent seawater indefinitely, according to Foster (1969).

The ability of fishes, including anadromous types, to tolerate high salinity conditions is related to stage of development. Yearling rainbow trout may tolerate salinities as great as 17 percent, while under-yearlings are quickly killed by only 6 percent (McKim et al. 1973). Similarly, Burnham and Peterka (1975) found that adult fathead minnows (a freshwater fish) could survive saline conditions as high as 16,000 µmhos/cm SEC, but reproduction was inhibited at 8,000 µmhos or more, due to death of eggs and sac fry.

Salinity itself may have a toxic effect on fishes by influencing the ability of fishes to maintain internal ionic stability. Moreover, the nature of the cations and anions which contribute to salinity, and their possible antagonistic and synergistic effects, are also of importance in determining toxicity. In addition to the markedly different toxicities of certain cations, significant differences in the toxicities of anions have also been reported. Peterka (1972), for example, has reported that fathead minnows can survive total dissolved solids (TDS) concentrations exceeding 15,000 ppm in sulfate waters but were unable to survive TDS levels exceeding 2000 ppm in bicarbonate waters.

TDS levels in the bicarbonate waters of Piceance Creek have reportedly exceeded 2000 ppm, primarily due to a fault in the aquifer near Black Sulphur Creek. This kind of change in water quality is similar to that which would be expected to occur in Piceance Creek or elsewhere as a result of oil shale mining and processing without proper safeguards to prevent leach waters from escaping into nearby receiving streams. This evidence suggests that oil shale mining leachates have the potential to affect adversely fishes having low bicarbonate-salinity tolerances.

REFERENCES

Andrews, A. K. 1970. The distribution and life history of the fathead minnow (*Pimephales promelas* Rafinesque) in Colorado. Ph.D. Thesis, Colorado State Univ., Fort Collins. 131 p.

Ashland Oil, Inc., and Shell Oil Co. 1975. Aquatic studies, p. 131-141. *In* Oil Shale Tract C-b, Environmental and Exploration Program. Summary Rep. No. 3, through May 31, 1975 (Report to U.S. Geological Survey, Grand Junction, Colorado). 164 p.

Baxter, G. T., and J. R. Simon. 1970. Wyoming fishes. Bull. No. 4, Wyoming Game and Fish Dep., Cheyenne. 168 p.

Brown, C. J. D. 1952. Spawning habits and early development of the mountain whitefish *Prosopium williamsoni* in Montana. Copeia 1952: 109-113.

Burnham, B. L., and J. J. Peterka. 1975. Effects of saline water from North Dakota lakes on the survival of fathead minnows (*Pimephales promelas*) embryos and sac fry. J. Fish. Res. Board Can. 32: 809-812.

Chipman, R. K. 1959. Studies of tolerance of certain freshwater fishes to brine water from oil wells. Ecology 40: 229-302.

Everhart, W. H., and B. E. May. 1973. Effects of chemical variations in aquatic environments. Vol. I. Biota and chemistry of Piceance Creek. Ecol. Res. Ser. No. EPA-R3-73-011a, Environmental Protection Agency, Washington, D.C. 117 p.

Foster, M. A. 1969. Ionic and osmotic regulation in three species of *Cottus* (Cottidae, teleost). Comp. Biochem. Physiol. 30: 751-759.

Frazer, J. C. 1972. Regulated stream discharge for fish and other aquatic resources; an annotated bibliography. Food and Agric. Organ. of the United Nations Fisheries Technical Paper No. 112, FIRI/T112, 103 p. (F.A.O., Rome 1972).

Goettl, J. P., and J. W. Edde. Environmental effects of western coal surface mining. Part I - The fishes of Trout Creek, Colorado. Ecol. Res. Ser., Office of Research and Development, U.S. Environmental Protection Agency, Duluth, Minn. (In Prep.)

Gordon, M. S. 1959. Ionic regulation in the brown trout (*Salmo trutta* L.). J. Exp. Biol. 36: 227-252.

Grande, M. 1967. Effect of copper and zinc on salmonid fishes. Proc. 3rd Int. Conf. Water Pollut. Res., Munich, 1966. 1: 96-111.

Holden, P. B., and C. B. Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. Trans. Am. Fish. Soc. 104(2): 217-231.

Kraft, M. E. 1968. The effects of controlled dewatering on a trout stream. M. S. Thesis, Montana State Univ., Bozeman. 31 p.

Leslie, P. H., and D. H. S. Davis. 1939. An attempt to determine the absolute number of rats on a given area. J. Anim. Ecol. 8: 94-113.

McCormick, J. H., K. E. F. Hokanson, and B. R. Jones. 1972. Effects of temperature on growth and survival of young brook trout, *Salvelinus fontinalis*. J. Fish. Res. Board Can. 29(8): 1107-1112.

McKim, J. M., G. M. Christensen, J. H. Tucker, and M. J. Lewis. 1973. Effects of pollution on freshwater fish. J. Water Pollut. Control Fed. 45(6): 1370-1407.

Moussavi, M., and T. F. Yen. 1976. Environmental improvements by oil shale leaching, p. 205-220. *In* T. F. Yen (ed.) Science and technology of oil shale. Ann Arbor Science, Ann Arbor, Michigan.

Moyle, P. B. 1976. Some effects of channelization on the fishes and invertebrates of Rush Creek, Modoc County, California. California Fish and Game 62(3): 179-186.

Parry, G. 1960. The development of salinity tolerance in the salmon, *Salmo salar* (L.) and some related species. J. Exp. Biol. 37: 425-434.

Peterka, J. J. 1972. Effects of saline waters upon survival of fish eggs and larvae and upon the ecology of the fathead minnow in North Dakota. PB-223 017, Natl. Tech. Inf. Serv., Springfield, Virginia 22161.

Petrosky, C. E., and T. F. Waters. 1975. Annual production by the slimy sculpin population in a small Minnesota trout stream. Trans. Am. Fish. Soc. 104(2): 237-244.

Pettus, D. 1974. Inventory and impact analysis of fishes: Piceance Creek basin, Rio Blanco and Garfield Counties, Colorado. Report to Thorne Ecological Institute, Boulder, Colorado. 13 p.

Schmidt-Collesus, J. J., F. Bonomo, K. Gala, and L. Leffler. 1976. Polycondensed aromatic compounds (PCA) and carcinogens in the shale ash of carbonaceous spent shale from retorting of oil shale, p. 115-156. *In* T. F. Yen (ed.) Science and technology of oil shale. Ann Arbor Science, Ann Arbor, Michigan.

Skogerboe, R. K., C. S. Lavallee, M. M. Miller, and D. L. Dick. Environmental effects of oil shale mining and processing. Part III - The water quality of Piceance Creek, Colorado, prior to oil shale processing. Ecol. Res. Ser., Office of Research and Development, U.S. Environmental Protection Agency, Duluth, Minn. (In prep.)

Smith, G. R. 1966. Distribution and evolution of the North American Catostomid fishes of the subgenus *Pantosteus*, genus *Catostomus*. Misc. Pub. Mus. Zool., Univ. Mich. No. 129, Ann Arbor. 133 p.

Vincent, R. E., and W. H. Miller. 1969. Altitudinal distribution of brown trout and other fishes in a headwater tributary of the South Platte River, Colorado. Ecology 50(3): 464-466.

Woodling, J. D. 1974. Investigations of the aquatic ecosystems of Piceance and Yellow Creeks, northwestern Colorado. September and October 1974. Unpublished report from Colorado Dep. Health, Water Qual. Control Div. 13 p. + figs. + 5 tables.

Yen, T. F. 1976. Oil shales of United States--a review, p. 1-17. *In* T. F. Yen (ed.) Science and technology of oil shale. Ann Arbor Science, Ann Arbor, Michigan.